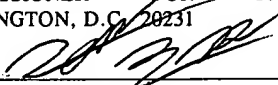


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System and Method for Testing Server Latencies
Using Multiple Concurrent Users in a Computer System

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BACKGROUND OF THE INVENTION

1. Field of the Invention

5 This invention relates generally to the field of computer systems and, more particularly, to testing server latencies in computer systems.

2. Description of the Related Art

10 Computer systems may include multiple clients coupled to a server. A server may be configured to store information such that the information may be accessed by multiple users using one of the clients. A server may operate using an operating system such as Solaris, Linux, Windows 2000, or Windows NT. An operating system may be configured to create users that may access files on the server. These users may be given varying access privileges to
15 information on the server and may be included in a group where each member of the group may be given a predefined set of access privileges within the system.

20 As computer systems become more powerful, servers and their operating systems may become able to support increasing numbers of users in a given system. As the number of users in the system increases, the number of tasks that the server may need to perform may also increase. The tasks of a server or more particularly, the operating system operating on the server, may include creating and deleting users, logging in and logging out users, performing accesses to files on the server on behalf of users, and possibly executing applications or other programs on the server. As the number of users and hence, the number of tasks increases, the latency in
25 performing a given task may increase as the task may not be completed until busy resources within the server become available. It would be desirable to measure server latencies in a system with multiple users. It would further be desirable to measure server latencies in a system with

coordinate the concurrent execution of instances of a test program for a set of users in the system. The test script may cause each client in the system to be reset, may cause a system clock to be synchronized, may cause a directory share to be created, and may cause an instance of a test program to be initiated for each of a set of users. Each instance of a test program may generate and store values that may be analyzed in accordance with the type of test being performed.

In one embodiment, a test program may be configured to generate and store latency values associated with accesses to files on the server in the system. A server may authenticate a user corresponding to the test program and may provide a token that may be used by the test program to access files on the server. The test program may cause files within the directory structure of the user to be enumerated into a table and may cause an order of these files to be generated according to a seed value using a random number generator. The test program may then cause read and write accesses to the files in the order generated by the random number generator. The test program may store a latency value associated with each access. Each successive access may be made to the same file as a previous access or to a different file as the previous access. When a file is first accessed, it may be opened on the server and the server may verify that the user associated with the test program has permission to perform an access to the file using the token. The time taken by the server to perform the verification may be reflected in the latency value stored by the test program.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the accompanying drawings in which:

Fig. 1 is a block diagram illustrating one embodiment of a computer system configured to test server latencies using multiple concurrent users.

Fig. 2 is a flow chart illustrating a method for testing server latencies using multiple concurrent users.

Fig. 3 is a flow chart illustrating a method for setting up a test environment.

Fig. 4a is a diagram illustrating a directory structure.

Fig. 4b is a diagram illustrating one example of populating a directory structure.

Fig. 5 is a table illustrating attributes of different user types for an example organization.

Fig. 6 is a diagram illustrating an example of populating the directory structures of multiple users.

Fig. 7 is a flow chart illustrating a method for concurrently executing instances of a test program.

Fig. 8a is a flow chart illustrating a method for initiating instances of a test program.

Fig. 8b is a first portion of a flow chart illustrating a method for testing server latencies.

Fig. 8c is a second portion of a flow chart illustrating a method for testing server latencies.

Fig. 9a is a table illustrating an example of a directory enumeration table.

Fig. 9b is a table illustrating an example ordering of a directory enumeration table using a first seed value.

Fig. 9c is a table illustrating an example ordering of a directory enumeration table using a second seed value.

Fig. 10 is a block diagram illustrating one embodiment of permission checking structures that may be used by an operation system.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present invention as defined by the appended claims.

DETAILED DESCRIPTION OF AN EMBODIMENT

Turning now to Fig. 1, a block diagram illustrating one embodiment of a computer system configured to test server latencies using multiple concurrent users is shown. Fig. 1 depicts server 100 coupled to clients 120a, 120b, and 120c through network 110. Clients 120a, 120b, and 120c may be configured to execute system processes 122a, 122b, and 122c, respectively. System processes 122a, 122b, and 122c may include operating system routines or other applications. Clients 120a, 120b, and 120c may also be configured to concurrently execute user0 test program 124a through user(m) test program 124(m), user(m+1) test program 124(m+1) through user(n) test program 124(n), and user(n+1) test program 124(n+1), respectively.

Clients 120a, 120b, and 120c are shown by way of example as other embodiments may include other numbers of clients coupled to server 100. Clients 120a, 120b, and 120c may also be configured to execute other types of programs. Clients 120a, 120b, and 120c may be referred

to individually as a client 120 or collectively as clients 120. User0 test program 124a through user(n+1) test program 124(n+1) may be referred to individually as a test program 124 or collectively as test programs 124. Each test program 124 may also be referred to as an instance.

5 Fig. 1 illustrates a system for testing server latencies using multiple concurrent users. Clients 120 may each be configured to concurrently execute one or more instances of a test program 124 on behalf of multiple users. Each user may be created on server 100 such that server 100 may login a user in response to that user attempting to access a file or other resource on server 100. Server 100 may create a home directory for each user and the home directory for
10 each user may be populated with a mix of files according to a user type for each user as described in more detail below. Each test program 124 may cause communications to take place with server 100 across network 110.

 Server 100 may authenticate a user for each test program 124 using the same or different
15 operating system protocols. In one embodiment, each instance of test program 124 may be configured to cause a series of accesses to one or more files in the directory of its respective user on server 100 and may be configured to cause a latency value to be measured and stored for each access that is performed. The latency values may be compiled by each instance of test program 124 and may be stored onto server 100 upon completion of each instance of test program 124.
20 The latency values measured by an instance of test program 124 may represent a first time portion that corresponds to the amount of time to perform a given access and a second time portion that corresponds to server 100 verifying that the user corresponding to this instance of the test program has permission to access the file. The accesses performed may include read accesses or write accesses.

25 Fig. 2 illustrates a method for testing server latencies using multiple concurrent users is shown. Variations on the method are possible and contemplated. Test setup actions may be performed as indicated in block 202. Example test setup actions may include creating users,

creating home directories for the users, and populating the home directories with files according to a user type of each user. Test programs may be concurrently executed using multiple users as indicated in block 204. A test program may, for example, measure and store latencies associated with file accesses. One embodiment of a test program is described below with respect to Figs. 8b and 8c. Test results generated by the test program may be stored as indicated in block 206 and the test results may be synthesized and analyzed as indicated in block 208.

Turning now to Fig. 3, a flow chart illustrating a method for setting up a test environment is shown. Variations on the method are possible and contemplated. Operating system attributes may be set as indicated in block 302. The attributes set may depend on the type of operating system employed by a server such as server 100 shown in Fig. 1.

In one embodiment where a server employs the Windows NT operating system, certain Advanced User Rights may be set to allow a user to impersonate another user. Under normal circumstances, Windows NT may prevent a user from impersonating another user for security reasons. This security enforcement may be overcome by setting the following Advanced User Rights.

1. Act as part of the Operating System
2. Create a Token
3. Increase quotas
4. Replace a process-level token

Once these Advanced User Rights are set, a server may support multiple users from a single client such as clients 120 shown in Fig. 1. A client 120 may use a token to launch multiple instances of test program 124 for different users. Client 120 may do so by copying the token and including impersonate bits in the new token when launching an instance of test program 124. In

doing so, each instance of test program 124 may be effectively executed by a different user and server 100 may interact with each instance as though it were being executed by a different user.

Referring back to Fig. 3, users and user profiles may be created as indicated in block 304 and a home directory may be created for each user as indicated in block 306. Users and corresponding user profiles may be created according to a user creation protocol of an operating system employed by a server. In one embodiment where a server employs the Windows NT operating system, users may be created using the Security Accounts Manager (SAM) database of the Primary Domain Controller (PDC) in a Windows NT domain. In addition, the access control list (ACL) for the home directory of each user may be set.

In one particular embodiment, users may be created using a CreateUsers program. The CreateUsers program may be executed on a client such as client 120 shown in Fig. 1. The CreateUsers program may be used to create a specified number of users and may be executed using the following variables.

Variable	Explanation
MINUSER	First user number
MAXUSER	Number of users to create
HOMEDIR	Location of home directory on server for all users created
HOMECOMPUTER	Location of server (PDC) for all users created
USER PREFIX	Prefix added to user number to create user name
USER POSTFIX	Postfix added to user number to create user name

For example, the following would create user1 to user500 in the current domain.

```
set MINUSER=1
set MAXUSERS=500
```

set HOMEDIR=c:\export\home\users
set HOMECOMPUTER=venom
set USERPREFIX=user
set USERPOSTFIX=
createusers

In this example, all users would be configured with \\venom\c\$\export\home\users as the directory where their individual home directories would be created. The home directories would be named user0, user1, user2, ..., user 499.

The CreateUsers program may use a MakeUsr program to create users and create a profile for each user. The syntax of the MakeUsr program may be:

makeusr user_name [password] [switches]

The switches for the MakeUsr program may include:

Switch	Explanation
/DOMAIN	Create a global user account in the domain versus a local user account on the local computer. (Default: local computer).
/LOCAL:local_group	Add account to the specified local_group. Multiple /LOCAL switches may be allowed. In addition, a list of groups may be supplied in the MULOCAL command shell variable.
/GLOBAL:global_group	Add account to the specified global_group. Multiple /GLOBAL switches may be allows. In

addition, a list of groups may be supplied in the MUGLOBAL command shell variable.

/FULLNAME:name

Specify full name for the account. Use quotes if the name contains spaces.

/PROFILEPATH: path

Profile path for this account.

```
/SCRIPTPATH:path
```

Logon script path for this account.

/HOMEDIR:path

User home directory. If /HOMECOMPUTER is not specified, this may be a local path. If /HOMECOMPUTER is specified, this is a local path relative to that computer (e.g. C: refers to C: on that computer).

/HOMECOMPUTER:name

Computer to contain home directory. (Default: local computer).

```
/HOMEPROTO:uncpath
```

Unified naming convention (UNC) name of the prototype home directory. May be copied to the home directory when created.

/COMMENT:text

Text comment for this user name

Additional options may be set up by initializing command shell variables prior to executing the MakeUsr program.

A CleanUser program may be used to remove users from the SAM database of a PDC. The CleanUser program may use the following variables.

Variable	Explanation
MINUSER	First user number
MAXUSER	Last user number
USER PREFIX	Prefix added to user number to create user name

USER POSTFIX

Postfix added to user number to create user name

For example, the following would delete user100 to user200 in the current domain.

```
set MINUSER=100
set MAXUSERS=200
set USERPREFIX=user
set USERPOSTFIX=
cleanuser
```

Fig. 4a is a diagram illustrating generally the creation of a home directory for each user. As may be seen, home directories \user0 and \user1 through \user(n) where n represents the (n-1)th user may be created in a directory named \users. The directory \users may be created anywhere within the directory structure of a server. In Fig. 4a, the root directory of a server may be named \\server and the dashed lines indicate paths to other directories within the directory structure. The directory \users may be directly under the root directory \\server or any number of directories may be included between the root directory \\server and the directory \users.

Referring back to Fig. 3, each home directory may be populated according to a user type as indicated in block 308. The home directory of each user may be populated with a set of files that corresponds to a user type for that user. A test program may be configured to perform accesses to these files. Fig. 4b illustrates one example of a home directory populated with files and a directory structure. Fig. 4b shows the directory of user(n), \user(n), populated with files f1, f2, f3, f4, f5, and f6 using directories \d1, \d2, \d3, \d4, \d5, and \d6 as shown. The size of each file f1 through f6 may vary according to a user type for user(n). In addition, the directory structure, i.e. the arrangement of directories \d1 through \d6, may vary according to a user type for user(n). Other home directories may be populated with other numbers and sizes of files as well as other directory structures.

By populating the home directory of a user according to a user type, the concurrent execution of an instance of a test program by multiple users may simulate a user load of an organization on a server. Organizations may comprise different types and number of users that access different sizes and types of files on a server. In order to simulate the user load of an organization, the number and type of users of the organization may be created. Instances of a test program may cause accesses to files in each user's home directory on the server according to a user's user type to simulate a user load of the organization on a server.

Fig. 5 is a table illustrating attributes of different user types of an example organization. Fig. 5 depicts users, file uses, file sizes, load rates, stress rates, and file load mixes for each user type. As shown in Fig. 5, the example organization may include three user types: small, medium, and large. The file uses and sizes indicate the use and size of files typically accessed by each user type. The load rate indicates a network transfer rate for each user type under typical conditions. The stress rate indicates a network transfer rate for each user type under stressed, i.e. test, conditions. The file load mix indicates the percentage of each of three respective files sizes: small, medium, and large. The small file size may refer to files that are 1-2 kilobytes, the medium file size may refer to files that are 20-80 kilobytes, and the large file size may refer to files that are 0.5 to 2 megabytes.

Users in the organization that correspond to the small user type, "small users", may be clerks such as sales assistants, inventory and stock clerks, and accounting clerks. The typical files accessed on a server by small users may be transaction records that are 1-2 kilobytes in size. Small users may have a load rate of 1 megabyte per hour and a stress rate of 6.7 megabytes per hour. Small users may access small files 70% of the time, medium files 20% of the time, and large files 10% of the time.

Users in the organization that correspond to the medium user type, "medium users", may be managers, secretarial workers, and administrative workers. Administrative workers may include human resource representatives, marketing personnel, and executives. The typical files accessed on a server by medium users may be memos and letters that are 20-80 kilobytes in size.

5 Medium users may have a load rate of 1.5 megabytes per hour and a stress rate of 10 megabytes per hour. Medium users may access small files 10% of the time, medium files 70% of the time, and large files 20% of the time.

Users in the organization that correspond to the large user type, "large users", may be technical and creative workers such as engineers, programmers, graphic and mechanical designers, and architects. The typical files accessed on a server by large users may be design files that are 0.5 to 2 megabytes in size. Large users may have a load rate of 1 megabyte per hour and a stress rate of 6.7 megabytes per hour. Large users may access small files 10% of the time, medium files 20% of the time, and large files 70% of the time.

Although the percentage of read accesses versus write accesses may be set by a test program, the default percentage may be set to 80% read accesses and 20% write accesses for each of the user types shown in Fig. 5.

It may be seen that an organization may be readily modeled using the above user types. For example, if the organization is an equipment supplier that designs, markets, and sells its own products, the personnel and the correspond user of types may be modeled as follows.

Department	Title	Number	User Type
Executive	President	1	Medium
	Vice-President	1	Medium
	Secretarial	1	Medium
Sales	Manager/Supervisor	1	Medium

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		Inside Sales Representatives	10	Small
		Outside Sales Representatives	5	Medium
		Secretarial	1	Medium
5	Marketing	Manager/Supervisor	1	Medium
		Marketing Specialists	4	Medium
		Secretarial	1	Medium
10	Engineering	Manager/Supervisor	1	Large
		Engineers / Technicians	6	Large
		Secretarial	1	Large
15	Finance / Accounting	Manager/Supervisor	1	Medium
		Accountant	1	Medium
		Clerks	3	Small
		Secretarial	1	Medium
20	Warehouse / Shipping	Manager/Supervisor	1	Medium
		Clerks	8	Small
		Secretarial	1	Medium
25	Human Resources	Manager/Supervisor	1	Medium
		Human Resources Representatives	3	Medium
		Secretarial	1	Medium
30	Facilities	Manager/Supervisor	1	Medium
		Maintenance Personnel	3	Small
		Secretarial	1	Medium

The above organization results in the following numbers per user type.

<u>User Type</u>	<u>Number</u>
Small	24
Medium	28
Large	8

Loading ratios from the above numbers may be derived as follows.

Small : Medium : Large = 24 : 28 : 8 = 3 : 3.5 : 1.

This ratio represents the mix of small, medium, and large user types that may be presented to a server under test. This user mix may provide a distribution of file accesses that is representative of an actual system such as the system shown in Fig. 1.

Turning now to Fig. 6, a diagram illustrating an example of populating the directory structures of multiple users is shown. As shown in Fig. 6, user home directories \user0, \user1, and \user2 may be created in a directory named \users. The directory \users may be created anywhere within the directory structure of a server. In Fig. 6, the root directory of a server may be named \\server and the dashed lines indicate paths to other directories within the directory structure. The directory \users may be directly under the root directory \\server or any number of directories may be included between the root directory \\server and the directory \users. Similarly, the directory \filemix may be directly under the root directory \\server or any number of directories may be included between the root directory \\server and the directory \filemix.

The directory \filemix may include the directories \small, \medium, and \large. The directory \small may include directory structure 602, the directory \medium may include directory structure 604, and the directory \large may include directory structure 606. Each directory structure 602, 604, and 606 may include a set of subdirectories and files. Directory structures 602, 604, and 606 may each correspond to a different user type. For example, directory structure 602 under the directory \small may correspond to a small user type such as the small user described above in Fig. 5. Similarly, directory structure 604 under the directory \medium may correspond to a medium user type such as the medium user described above in Fig. 5, and directory structure 606 under the directory \large may correspond to a large user type such as the large user described above in Fig. 5. Thus, directory structures 602, 604, and 606 may include a mixture of files and directories appropriate for their respective user types.

Fig. 6 illustrates a method of populating the home directories of a plurality of users. In the example of Fig. 6, user0 may correspond to a large user type, user1 may correspond to a small user type, and user2 may correspond to a medium user type. In order to populate the home directories for each of these users, the directory structure corresponding to each user's user type may be copied from the appropriate directory under the directory \filemix. As illustrated by arrow 616 in Fig. 6, directory structure 606 may be copied to the directory \user0 to populate the home directory of user0. Similarly, directory structure 602 may be copied to the directory \user1 to populate the home directory of user1 as illustrated by arrow 612, and directory structure 604 may be copied to the directory \user2 to populate the home directory of user2 as illustrated by arrow 614.

The method of populating a user's home directory shown in Fig. 6 illustrates one example of how a user's home directory may be populated. Numerous other methods are possible and contemplated. These other methods may include copying directory structures from a wider variety of user types that may have different file mixes than those described, generating directory structures for user types dynamically, or other methods that make files on a server available to a given user.

Turning now to Fig. 7, a flow chart illustrating a method for concurrently executing instances of a test program is shown. A test script may perform the method described in Fig. 7. Client systems may be reset as indicated in block 702. The clocks of the client systems may be synchronized as indicated in block 704. A directory share may be created as indicated in block 706. A directory share may be used to indicate a directory location of the home directories of the users. For example, a directory share "m:" may be created to refer to the directory \users shown in Fig. 6. A test program may be initiated for each user concurrently as indicated in block 708. Test results from each instance of the test program may be stored as indicated in block 710.

A flow chart illustrating a method for initiating instances of a test program as indicated in block 708 is shown in Fig. 8a. An instance of a test program may be launched for a user as indicated in block 802. A determination may be made as to whether an instance of the test program is to be launched for another user as indicated in block 804. If an instance of the test program is to be launched for another user, then the function performed in block 802 may be repeated.

Turning now to Figs. 8b and 8c, a flow chart illustrating a method for testing server latencies is shown. Each instance of the test program referred to in Fig. 7 may be configured to perform the method described in Figs. 8b and 8c. A user authentication may be performed according to an operating system protocol as indicated in block 806. A user may be logged in to a server using an operating system protocol of a client. The operating system protocols may include a UNIX desktop login method, Windows NT 4.0 Workstation login method, or Windows 2000 Professional login method. The server may validate the logon of the user. An access token may be received as indicated in block 807. The access token may be generated by the server and may be conveyed to the client that is executing the instance of the test program.

Directory enumeration of the files in the user's directory may be performed as indicated in block 808. Figs. 9a, 9b, and 9c illustrate an example of a directory enumeration table and examples of ordering a directory enumeration table using seed values. Figs. 9a, 9b, and 9c refer back to the directory structure shown in Fig. 4b. Directory enumeration table 900 lists the files in the user's directory structure using the directory share created in block 706 of Fig. 7. As may be seen, file 901 may be listed in directory enumeration table 900 as m:\d1\d3\fl. Files 902 through 906 may be listed similarly.

A file order may be randomized using a seed for a random number generator as indicated in block 810. In Fig. 9b, an ordering 910 of directory enumeration table 900 may be created using seed value n shown in seed 912. The seed value n of may be used by a random number

generator to create ordering 910 such that the random number generator may create the same ordering 910 of files 901 through 906 each time the seed value n is used. The order created by using seed value n in Fig. 9b is file 905, file 903, file 904, file 902, file 901, and file 906. Fig. 9c illustrates ordering 920 where seed value n+1, shown in seed 922, may be used. As may be seen, the order created by using seed value n+1 in Fig. 9c, file 904, file 902, file 906, file 905, file 903, and file 901, differs from that created by using seed value n in Fig. 9b.

The test program may be configured to access files (described below with respect to blocks 818 and 820) in the order created by the functions of blocks 808 and 810. In this manner, the results of a test program may be replicated by using the same seed value.

Blocks 812 and 814 indicate waiting for a start time to arrive before proceeding to block 816. The use of a start time may allow the access performed by each instance of the test program to begin concurrently. The chart of Fig. 8b may continue in Fig. 8c as indicated by the circled A.

A file open may be authorized using the access token as indicated in block 816. Fig. 10 illustrates one embodiment of permission checking structures that may be used by an operation system to authorize the opening of a file. Fig. 10 depicts file 1010 with its corresponding file access control list (ACL) 1000. File ACL 1000 may point to data structure 1020 that lists the permissions of each user to file 1010. As may be seen, user0 has read permission as shown in entry 1022, user1 has read and write permission as shown in entry 1024, user2 has no permissions as shown in entry 1026, and user(n) has write permission as shown in entry 1028. When a user's access token is presented to the server where the user seeks to access file 1010, the server may reference file ACL 1000 to determine whether that user has permission to access file 1010.

Once the file open has been authorized, a file may be opened as indicated in block 818. A read or write access may be performed as indicated in block 820. The latency to perform the

read or write access may be measured as indicated in block 822. The latency measurement may include the time to perform the file access as well as the time to authorize the opening of the file. The latency and access information may be stored as indicated in block 824.

5 A determination may be made as to whether the test is complete as indicated in block 826. If the test is not complete, a determination may be made as to whether a new file will be used for a next access as indicated in block 828. If a new file will be used for a next access, then the current file may be closed as indicated in block 830 and the operation may continue at block 816 as indicated. If a new file will not be used for a next access, then the operation may continue
10 at block 820 as indicated. If the test is determined to be complete at block 826, then results may be stored into a file as indicated in block 832. The results may be stored onto the server.

In one particular embodiment of a test program, the test program may attempt to transfer a specified amount of data within a specified amount of time. If the amount of data to be
15 transferred is too great to be transferred during the time limit, then the test program may continue until all of the data is transferred. The amount of data to be read or written may be expressed as a ratio, where 1 is read only and 0 is write only. Thus, a ratio of 0.5 along with an amount of data to be transferred of 1 megabyte would indicate that the test program if to read 0.5 megabytes and write 0.5 megabytes.
20

Each instance of test program may not operate continuously. Rather, each instance may be configured to start up at regular, specifiable intervals to perform a part of the total workload. This allows breaks between user activity. For example, the break between activities could be 1, 10, or 60 seconds.
25

The test program may employ the follow parameters.

<u>Parameter</u>	<u>Explanation</u>
------------------	--------------------

Each instance of the test program may save its results in a separate file on the client in which it operates. The results may include the following fields for each access performed.

Field	Description
Field 1	Descriptor for operation (e.g. read or write)
Field 2	Time taken to transfer the data in milliseconds
Field 3	Number of bytes read or written
Field 4	Record size
Field 5	Data and time stamp of operation

The results may further include a summary line with the following fields.

Field	Description
Field 1	Summary descriptor
Field 2	Total read time for test in seconds
Field 3	Total bytes read during the test
Field 4	Bytes read per second
Field 5	Total number of files read
Field 6	Total write time for test in seconds
Field 7	Total bytes written during the test
Field 8	Bytes written per second
Field 9	Total number of files written

The results may be analyzed to determine how a server performed under a user load generated by the test program.

Although the embodiments above have been described in considerable detail, other versions are possible. Numerous variations and modifications will become apparent to those

skilled in the art once the above disclosure is fully appreciated. It is intended that the following claims be interpreted to embrace all such variations and modifications.

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